BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 02011

SUBJECT: Comparison of AAP-2 Launch Windows and Launch Opportunities with the SWS at 35 and 50 Degree Inclinations - Case 610

DATE: February 10, 1970

FROM: W. L. Austin

ABSTRACT

The increase in SWS orbital inclination from 35 to 50 degrees significantly affects the AAP-2 launch window, growth margin and the number of launch opportunities. For a 1000 lb AAP-2 payload penalty, the launch window is reduced in length from 34 to 18.5 minutes, and the growth margin is reduced from 2980 to 1939 lbs. AAP-2 can be launched on four consecutive days after AAP-1, instead of five.

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MEMORANDUM FOR FILE

Introduction

Because of new earth resource experiment requirements, the Saturn Workshop (SWS) orbital inclination has been increased from 35 to 50 degrees. The orbit remains circular at 235 nm altitude.

The purpose of this memorandum is to discuss the impact of the orbital inclination change on the AAP-2 launch window and launch opportunities. The launch window and launch opportunities for the 35 and 50 degree inclinations are discussed and compared in the following sections.

Comparison of Launch Windows

The launch window is defined as the period of time during which the AAP-2 launch vehicle can insert the CSM into the proper orbit with respect to the SWS orbit with an acceptable payload penalty. Acceptable payload penalty is arbitrarily defined as 1000 lbs. Figures 1 and 2 show the AAP-2 launch window sizes and opportunities for 35 and 50 degree inclined SWS orbits respectively.

Plotted on the top half of Figures 1 and 2 are the AAP-2 yaw rate, payload penalty, and optimum launch azimuth* vs the time from the center of the window. In both cases, the AAP-2 CSM is always inserted at the perigee of an 81 x 120 nm orbit. The time from the center of the window is the time in minutes from an in-plane AAP-2 launch. Launches at times other than time 0 require yaw steering which results in a payload penalty. The lower half of each figure is applicable to the section on launch opportunities and will be discussed there.

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*At the present time, the S-IB software does not include a variable launch azimuth capability. However, this capability can easily be added to the S-IB software (Reference 1).

Comparing the two figures, it is readily seen that increasing the SWS orbital inclination to 50 degrees reduces the size of the AAP-2 launch window from 34 to 18.5 minutes for a 1000 lb payload penalty. Not shown in the figures, however, is the payload capability (weight above the instrument unit (IU)) of the AAP-2 launch vehicle. For an in-plane launch and perigee insertion into an 81 x 120 nm orbit, our simulations show an AAP-2 launch vehicle payload capability of 38,970 and 37,929 lbs for inclinations of 35 and 50 degrees respectively. These figures were determined using the BCMASP simulator and include the SLA and allow for a flight performance reserve of 1112 lbs. This is a reduction of 1041 lbs in S-IB payload capability which is equivalent to a 1041 lb reduction in the AAP-2 growth margin. At present, the AAP-2 weight above the IU (spacecraft and SLA) is 34,990 lbs (Reference 2). Assuming a 1000 lb allocation for yaw maneuvers, the AAP-2 growth margin is reduced from 2980 to 1939 lbs due to the inclination change.

Another effect of increasing the SWS orbital inclination to 50 degrees is that more northerly launch azimuths are required. Launch azimuths for the 35 degree orbit range from 73.8 to 60.0 degrees. For the 50 degree orbit, launch azimuths range from 52.5 to 36.7 degrees. Because of the more northerly launch azimuths, a limited analysis of AAP-2 radar tracking from launch to insertion, and the instantaneous impact points (IIP's) was done for the 50 degree inclined orbit.

Figure 3 shows the AAP-2 tracking coverage for launch azimuths of 54 and 36 degrees from launch to insertion into a 50 degree inclination orbit. Clearly, tracking coverage is continuous from launch to insertion. However, a potential problem area is the single station coverage by Bermuda from approximately 445.0 seconds to insertion. A tracking problem would arise if Bermuda failed to acquire or has an equipment failure. The likelihood of these two possibilities is currently being investigated.

Figure 4 shows approximate AAP-2 IIP curves over a range of launch azimuths from 52 to 36 degrees. These curves were generated by computing a conic no-drag trajectory at each integration step in the powered flight trajectory. The point of impact then is the first intersection of the conic with a spherical earth after apogee passage.

Over the entire range of launch azimuths, all S-IB impact points occur in water. Since the S-IVB is nominally inserted into orbit, an impact problem can only arise should an abort requiring early shutdown of the S-IVB occur. As the map shows, the IIP does traverse the European land mass, but very quickly at the end of the S-IVB burn. Whether or not a nominal trajectory with these IIP characteristics is acceptable has not yet been decided.

Comparison of Launch Opportunities

The lower half of Figures 1 and 2 show the AAP-2 in-plane launch opportunities for M = 3, 4, 5, and 17 rendezvous for a period of 15 days after the SWS launch*. The M number is the AAP-2 orbit number during which rendezvous occurs. These launch opportunities were generated utilizing program "LWPANE" (Reference 3), and are based on an optimum SWS launch (no yaw steering).

Table I shows the sequence of events and the number of orbits between the events used in program "LWPANE" to determine the launch opportunities for M = 3, 4, and 5 rendezvous. The variation in apogee and perigee and the number of orbits from NC1 to NC2 and NC2 to NSR define the phasing capability. The total ranges in central angle caught up are 10.46, 20.89, and 31.32 degrees for M = 3, 4, and 5 respectively.

For M = 17 there are two catch-up modes (fast and slow) for AAP-2. In the fast mode, NC1 is used as the phasing maneuver and in the slow mode NC2 is used as the phasing maneuver. Table II shows the sequence of events, apogee/perigee variations and number of orbits between maneuvers for the fast and slow catch-up modes of the M = 17 rendezvous. Adding the phasing capability of the two modes, the total range in central angle is 185.78 degrees.

Figure 1 shows that for the 35 degree inclination a launch opportunity exists for AAP-2 on each of five consecutive days after the SWS launch. A fast rendezvous (M = 3, 4, or 5) can be used on days 1 and 2; a slow rendezvous (M = 17) is available on days 2, 3, 4, and 5. The pattern repeats every 7 days.

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*The M = 17 opportunities include an AAP-2 ascending node bias to compensate for the differences in nodal regression of the AAP-2 and SWS orbits from AAP-2 insertion through rendezvous.

Referring to the 50-degree case shown in Figure 2, launch opportunities are available for 4 consecutive days after the SWS launch. Fast rendezvous is available only on the first day and the fourth day's launch opportunity is shortened. The pattern of 4 launch opportunities every 5 days repeats indefinitely.

Figures 1 and 2 were generated with the SWS launch directly into orbit with no yaw maneuver. The exact relationship between the launch window center and the CSM launch opportunities can be biased slightly by yawing the SWS and thereby shifting the orbit node. Figure 5 (used with the enclosed overlay) shows the effect yaw steering the SWS has on the occurrence of in-phase opportunities for the 50 degree inclination.

To use the overlay, superimpose the horizontal scale of the overlay on the time in minutes from center of the window scale in the upper part of Figure 5. For a desired shift in SWS ascending node, move the overlay horizontally until its 0 point is above a desired value on the shift in SWS ascending node scale. AAP-2 launch opportunities for a particular shift in ascending node are those which fall between the dashed vertical lines (1000 lb payload penalty limits) on the overlay. For example, to obtain the launch opportunities shown in Figure 2, vertically align the 0 on the overlay with the 0 point on the shift in ascending node scale.

Any shift in the SWS insertion ascending node will result in a payload penalty for the SWS. Figure 6 shows the payload penalty, yaw rate, and optimum launch azimuth vs shift in insertion ascending node for the SWS. For example, a shift of 0.9 degree results in extending the duration of the day 4 opportunity to 10 minutes without affecting the duration of the opportunities for days 1 through 3. Referring to Figure 6, the SWS payload penalty is 600 lbs.

Summary

The increase of the SWS orbital inclination to 50 degrees significantly affects the AAP-2 launch window and the number of launch opportunities. For a 1000 lb AAP-2 payload penalty, the launch window is reduced in length from 34 to 18.5 minutes, and the growth margin is reduced from 2980 to 1939 lbs. Launch azimuths are considerably more northerly resulting in possible tracking and IIP problems. AAP-2 can be launched on 4 consecutive days after AAP-1, instead of 5.

Even though AAP-2 tracking coverage is continuous from launch to insertion, Bermuda is the only station tracking the vehicle for a significant portion of the S-IVB burn. The probability that Bermuda would not acquire or drop out while tracking is currently being investigated.

The IIP analysis presented in this memorandum is a limited one as conic no-drag trajectories were used to compute the impact points. However, it does show that some portion of the S-IVB burn will result in land impacts (Europe) in case of abort.

Acknowledgment

The writer wishes to gratefully acknowledge the efforts of I. Hirsch in generating the tracking data, IIP curves, and the payload penalty data.

W. L. Austin

1025-WLA-li W. L. Austin

Attachments

REFERENCES

1. Trip Report: AAP Cluster Systems Design Review - Mission Requirements Team - Case 610, Memorandum for File, D. A. Corey, December 15, 1969.

2. AAP Weight and Performance Report for November 1969, MSC, November 15, 1969.

3. W. L. Austin, "LWPANE" A Program for Determining Launch Windows and Launch Opportunities - Case 610", Memorandum for File (In Preparation).

TABLE I SEQUENCE OF EVENTS AND ORBITS FOR M = 3, 4, and 5 RENDEZVOUS

Maneuver	No. of Orbits			Orbits	Remarks
	M = 3	M = 4	M = 5		
Insertion	1/2	1/2	1/2	81 x 120	Perigee Insertion
NC 1	1/2	1 1/2	2 1/2	120x81 to 120x225	NC 1 performed at 120 mi; opposite pericentron may range from 81 to 225 mi.
NC 2	1/2	1/2	1/2	$(81 \rightarrow 225) \times 225$	Perigee altitude is the altitude of the NC 2 burn and apogee altitude is defined by the NSR altitude
NSR	$\approx 1/2$	$\approx 1/2$	$\approx 1/2$	225 x 225	Δh = 10 n.m.
TPI	$\approx \frac{140}{360}$	$\approx \frac{140}{360}$	$\approx \frac{140}{360}$	225 x 236.3	Based on a transfer angle of 140 degrees
TPF				235 x 235	SWS altitude

TABLE II SEQUENCE OF EVENTS AND ORBITS FOR M = 17 RENDEZVOUS

Manuever	No. of Orbits		Orbits		Remarks
	Fast	Slow	Fast	Slow	
Insertion					
	1 1/2	1 1/2	81 x 120	81 x 120	Perigee Insertion
NC 1					
	13 1/2	1/2	120x106 to 120x225	120x106 to 120x205	
NC 2					
	1/2	13 1/2	$(106 \rightarrow 225)$ x 225	$(106 \rightarrow 205)$ x 225	In the slow mode the closest approach for the phasing orbit is $\Delta h = 20$ n.m.
NSR					
	$\approx 1/2$	$\approx 1/2$	225 x 225	225 x 225	$\Delta h = 10$ n.m.
TPI					
	$\approx \frac{140}{360}$	$\approx \frac{140}{360}$	225 x 236.3	225 x 236.3	Based on a transfer angle of 140°
TPF					
			235 x 235	235 x 235	SWS altitude

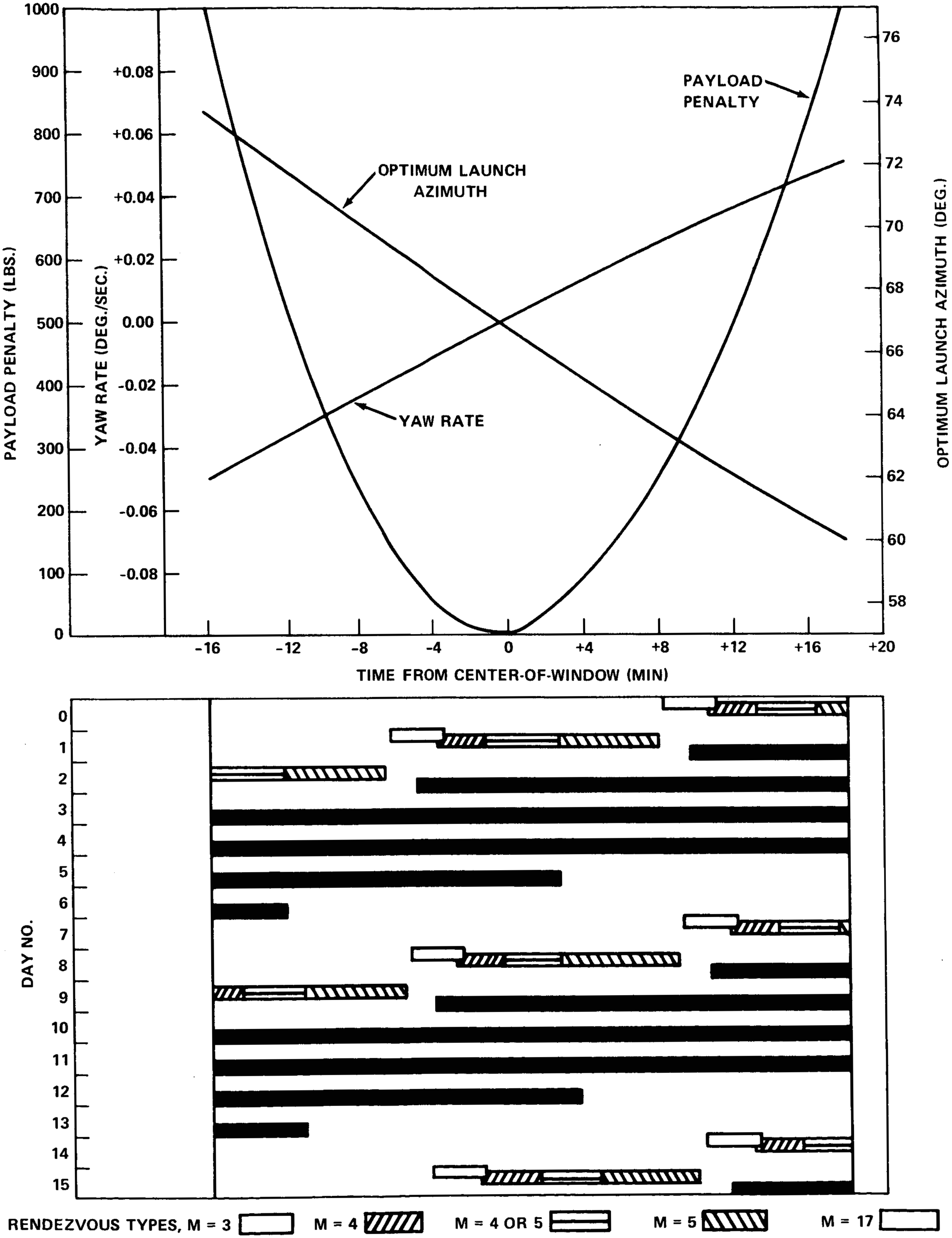


FIGURE 1. AAP-2 NORTHERN LAUNCH WINDOW AND LAUNCH OPPORTUNITIES (INCLINATION = 35 DEGREES)

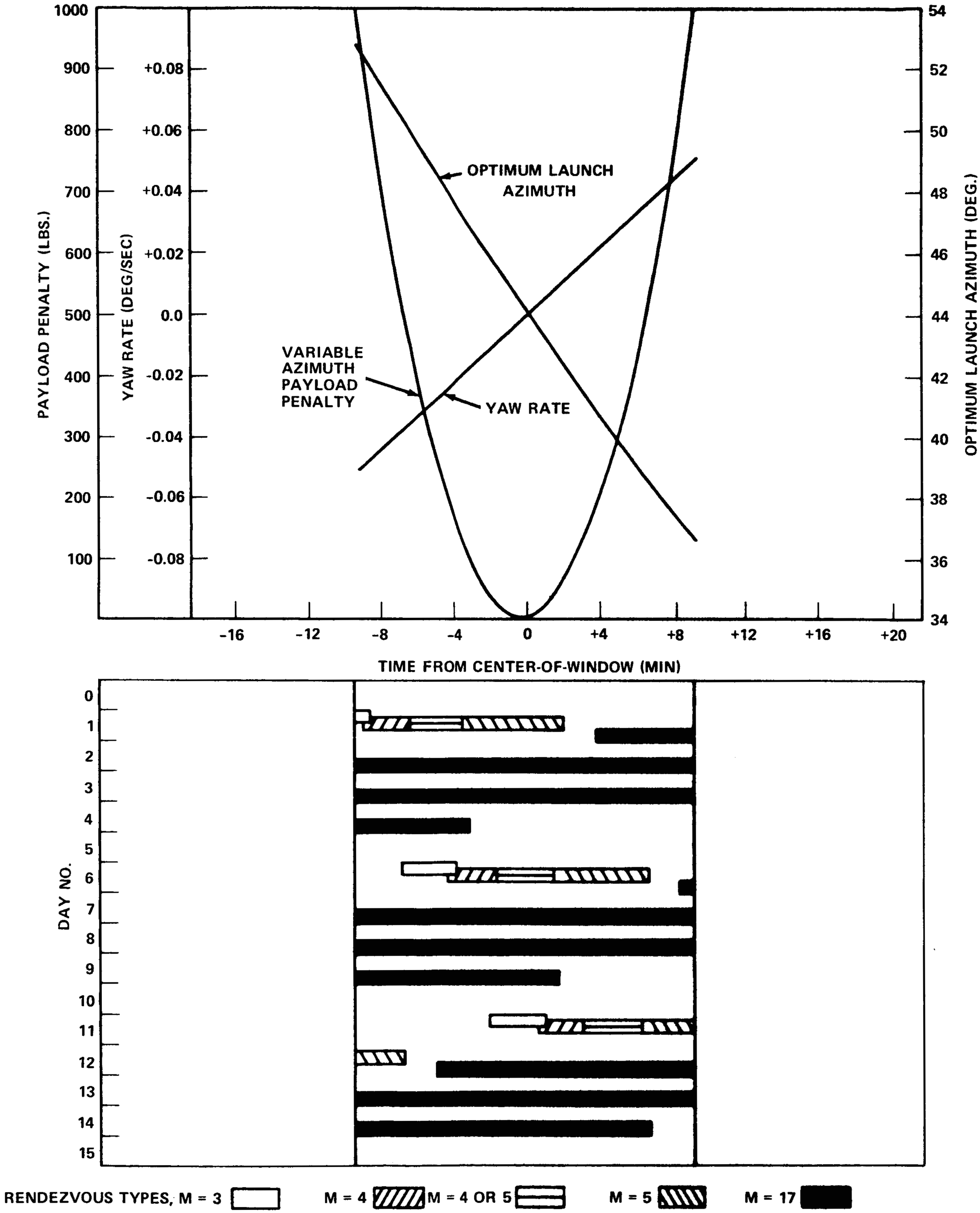


FIGURE 2. AAP-2 NORTHERN LAUNCH WINDOW AND LAUNCH OPPORTUNITIES
(INCLINATION = 50 DEGREES)

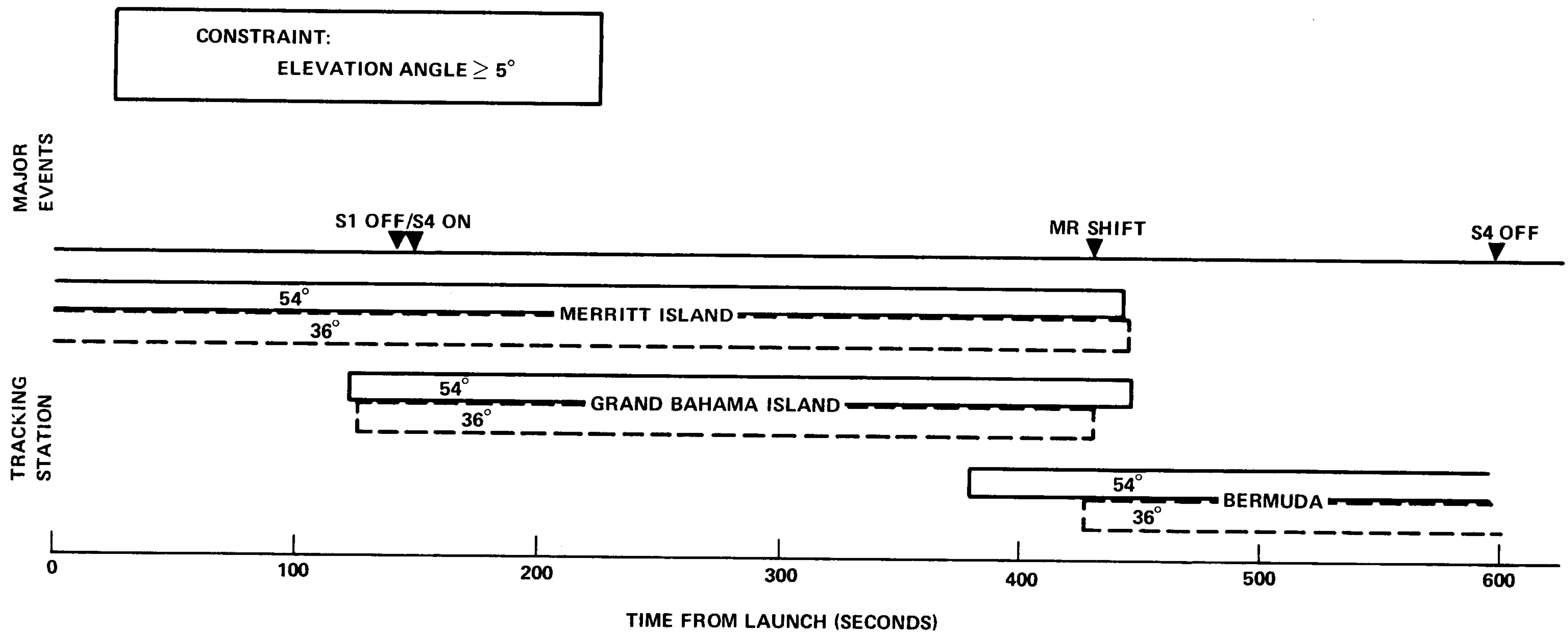


FIGURE 3. GROUND TRACKING COVERAGE OF CM/SM FROM LAUNCH TO ORBITAL INSERTION AT 50° INCLINATION FOR LAUNCH AZIMUTHS OF 36° AND 54°

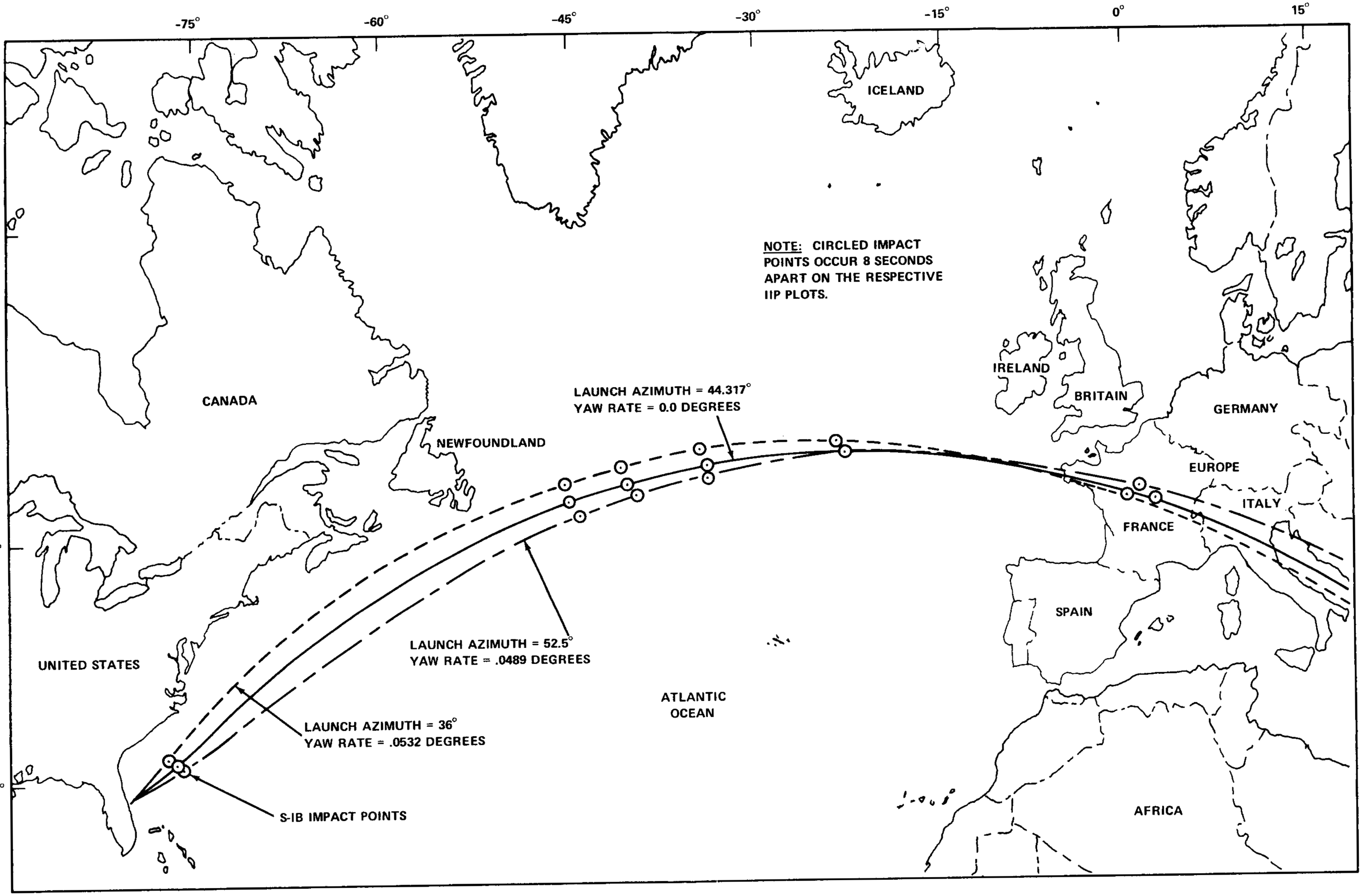
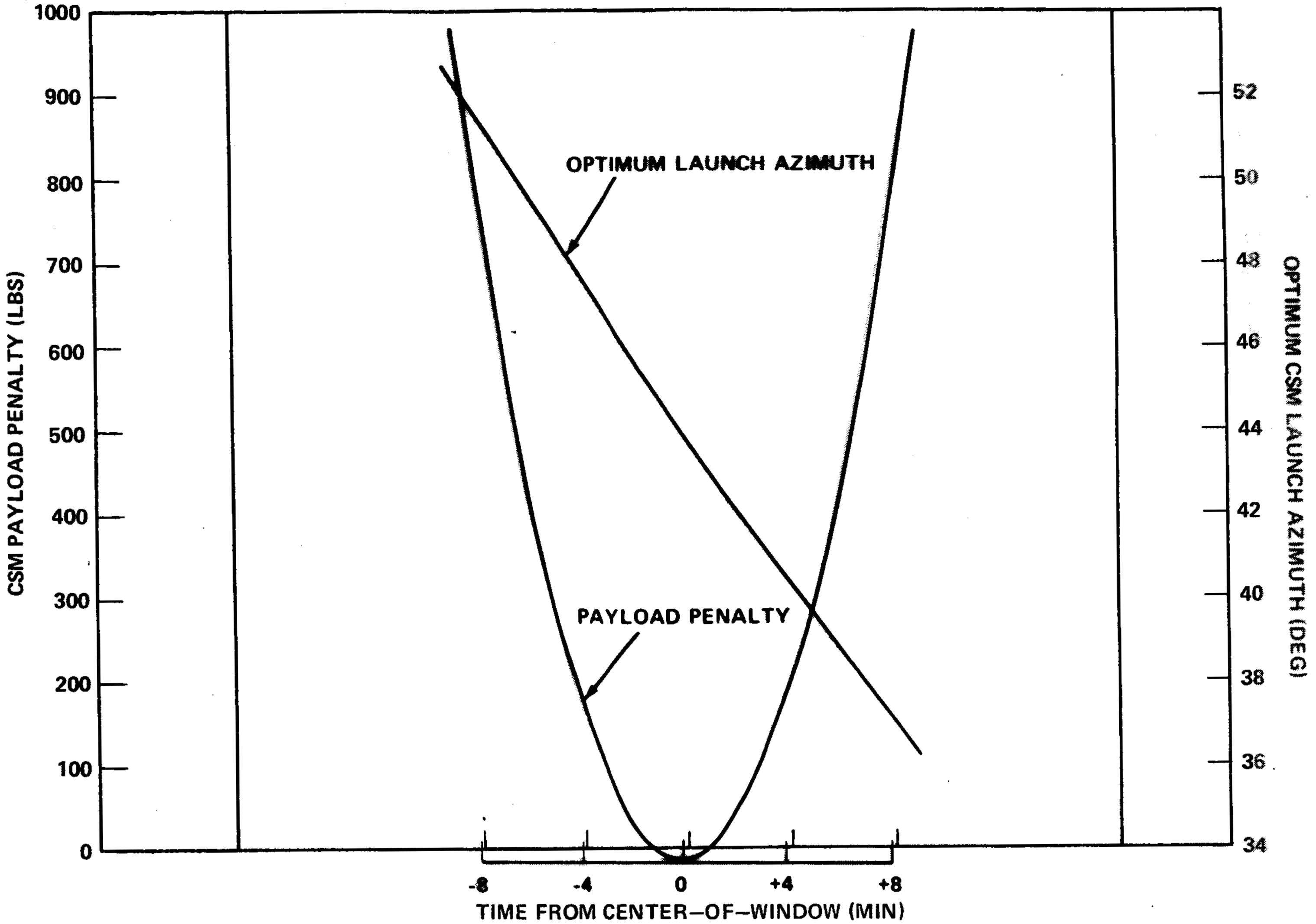
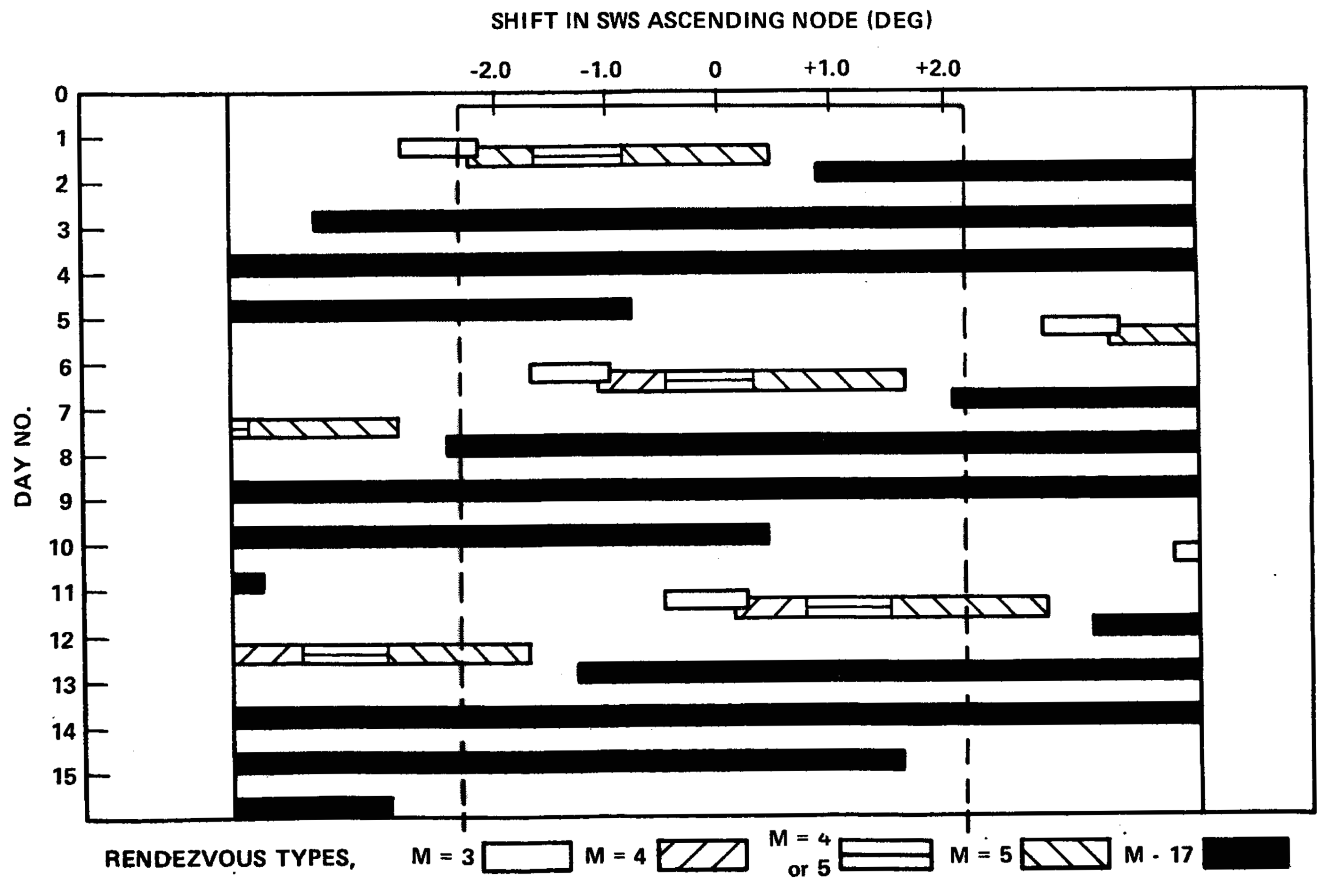


FIGURE 4. INSTANTANEOUS IMPACT POINTS FOR 50° INCLINATION MISSIONS WITH NORTHERN LAUNCH AZIMUTHS


CSM PAYLOAD PENALTY (LBS)
1000
900
800
700
600
500
400
300
200
100
0
OPTIMUM LAUNCH AZIMUTH
PAYLOAD PENALTY
OPTIMUM CSM LAUNCH AZIMUTH (DEG)
52
50
48
46
44
42
40
38
36
34
-8
-4
0
+4
+8
TIME FROM CENTER–OF–WINDOW (MIN)


SHIFT IN SWS ASCENDING NODE (DEG)
-2.0
-1.0
0
+1.0
+2.0
DAY NO.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
RENDEZVOUS TYPES,
M = 3
M = 4
M = 4 or 5
M = 5
M - 17

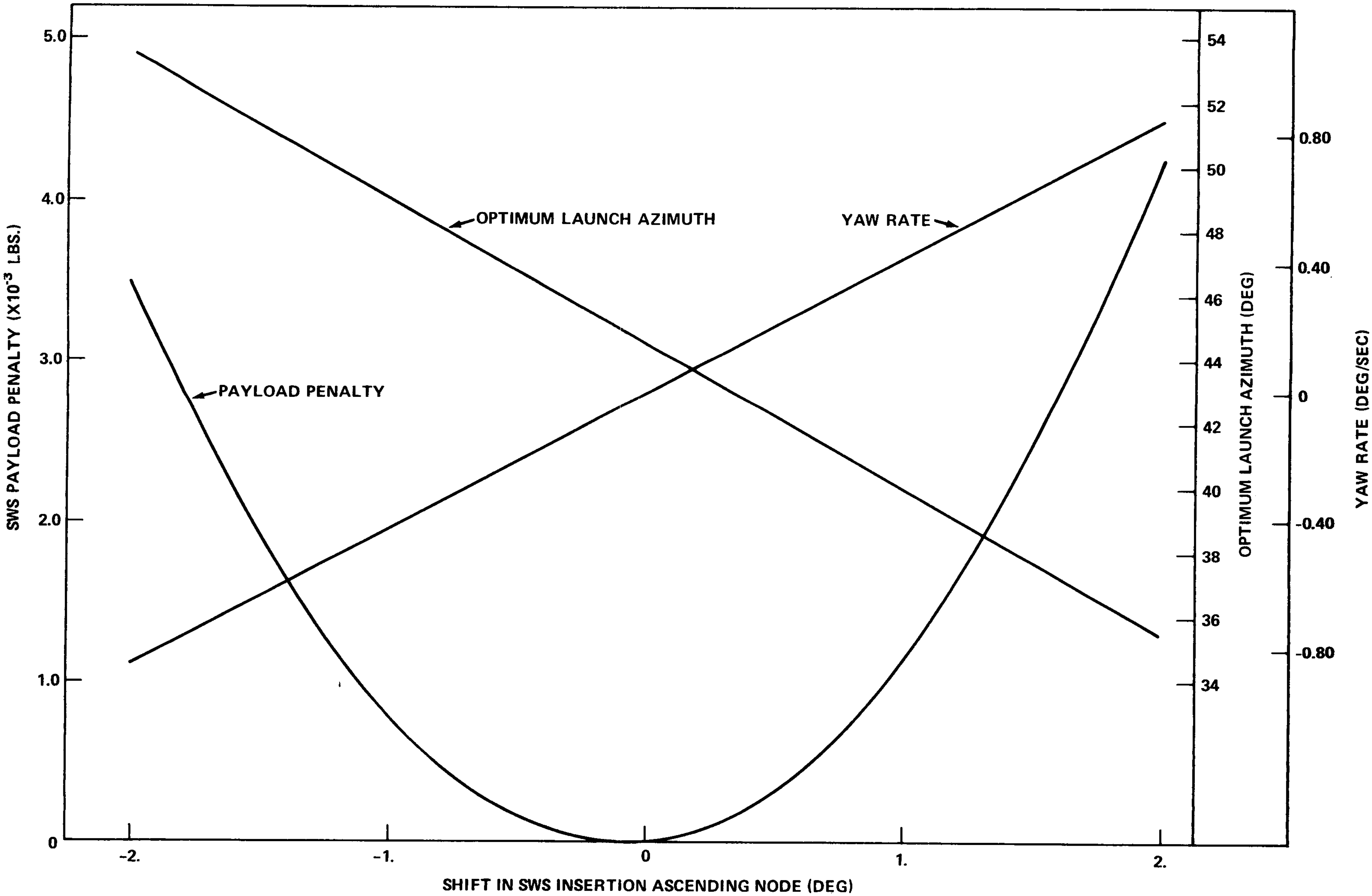


FIGURE 6. SWS PAYLOAD PENALTY VS. SHIFT IN INSERTION ASCENDING NODE

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